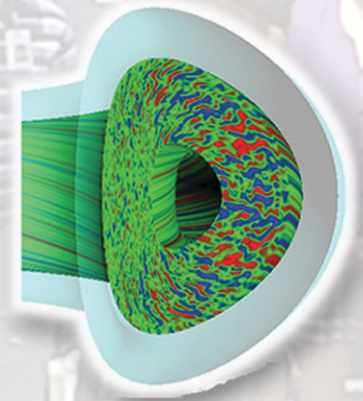
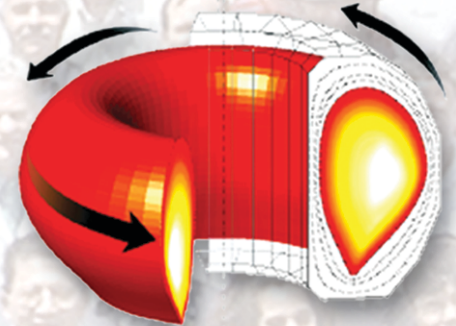


Edge and Boundary Topical Science Area

by
S. L. Allen

Presented at
PFC Meeting

February 28, 2006



Boundary TSA working groups are organized around physics issues

- **PSI group (Groth) 3/2/4 WG request/12wk/32 wk**
 - ITER tritium inventory and carbon transport
 - ITER mirror and tile gap tests
- **Heat Flux Control and Fueling (Petrie) 2/1/4**
 - Puff and pump in ITER Hybrid and AT plasmas
- **Transport & ELMs (Boedo) 1/0/2**
 - Poloidal dependence of transport, ELM effects
- **AT Divertor (Mahdavi) 2/2/4**
 - Commission new divertor in AT shape
 - Compare pumping with predictions
 - Dome shape for ITER

(Assumes no ^{13}C exposure in 2006)

Argon “Puff and Pump” enrichment is greater in the closed upper divertor - ITER “dome” issue

$$\text{Enrichment} = (f_{\text{EXH}})/(f_{\text{CORE}})$$

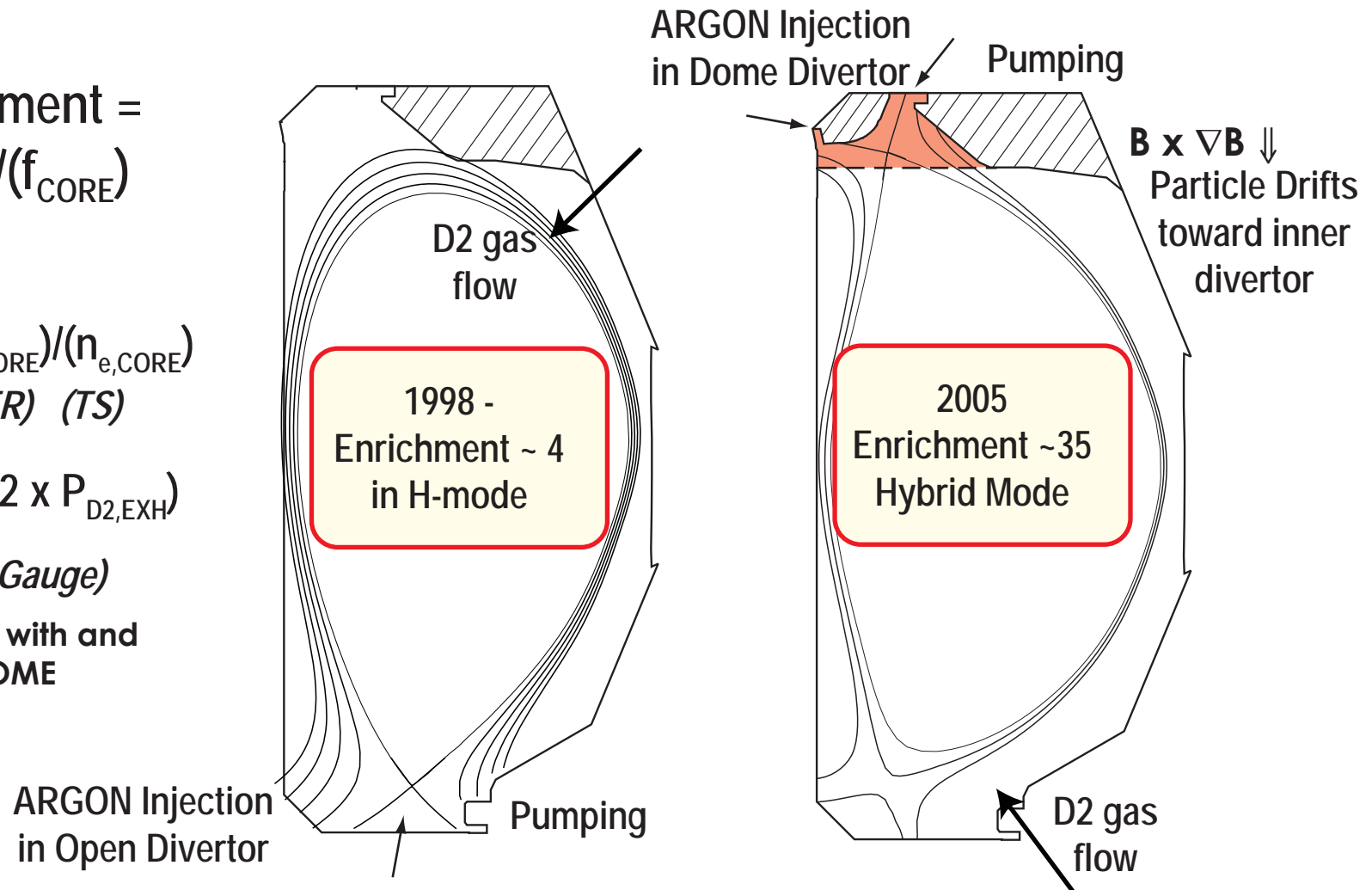
$$f_{\text{CORE}} = (n_{\text{Z,CORE}})/(n_{\text{e,CORE}})$$

(CER) (TS)

$$f_{\text{EXH}} = (P_{\text{Z,EXH}})/(2 \times P_{\text{D2,EXH}})$$

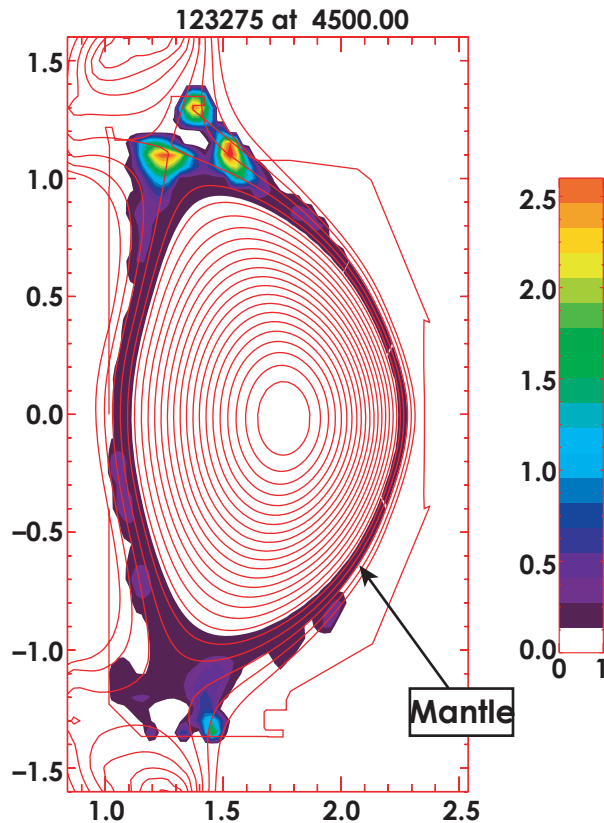
(Penning Gauge)

2006: Compare with and without DOME

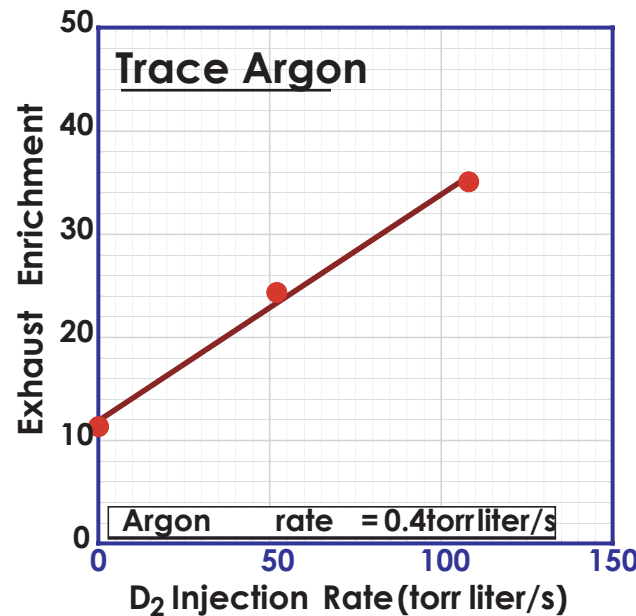


The Radiative Divertor was Successfully Applied to “Hybrid” Operation

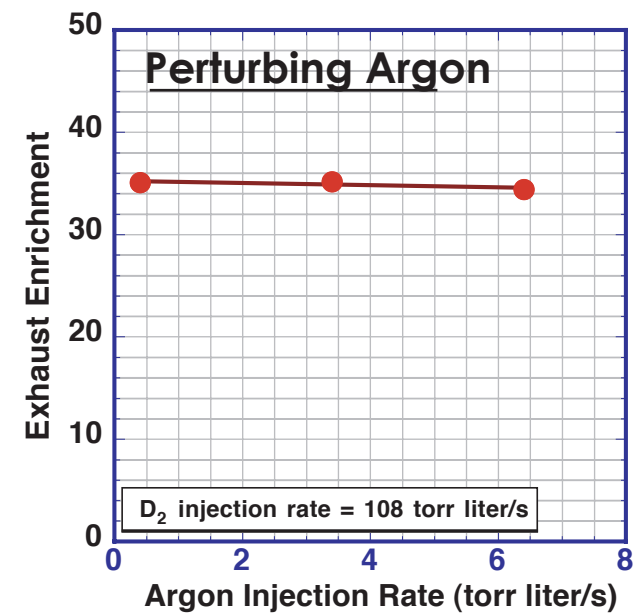
$$\text{Enrichment} \equiv \frac{f_{\text{exh}}}{f_{\text{core}}}$$



$P_{\text{rad}}/P_{\text{tot}} = 0.62$
 $\beta_N = 2.5$
 $H_{89p} = 2.0$



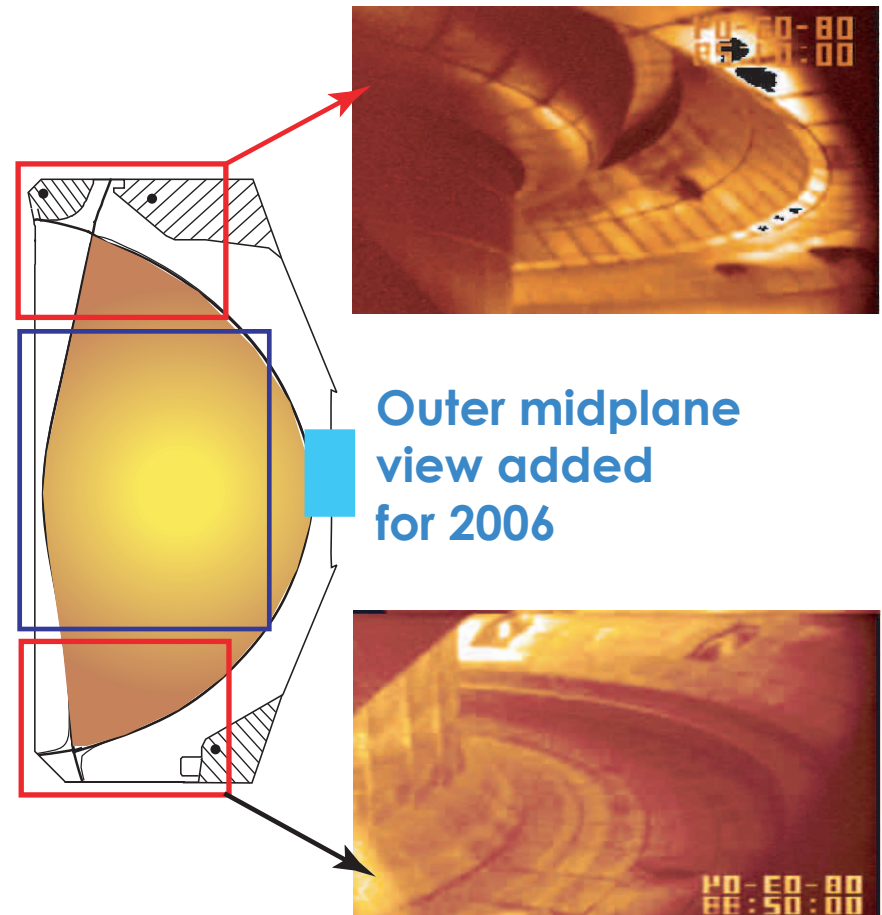
Enrichment of trace argon increased with Γ_{D2}



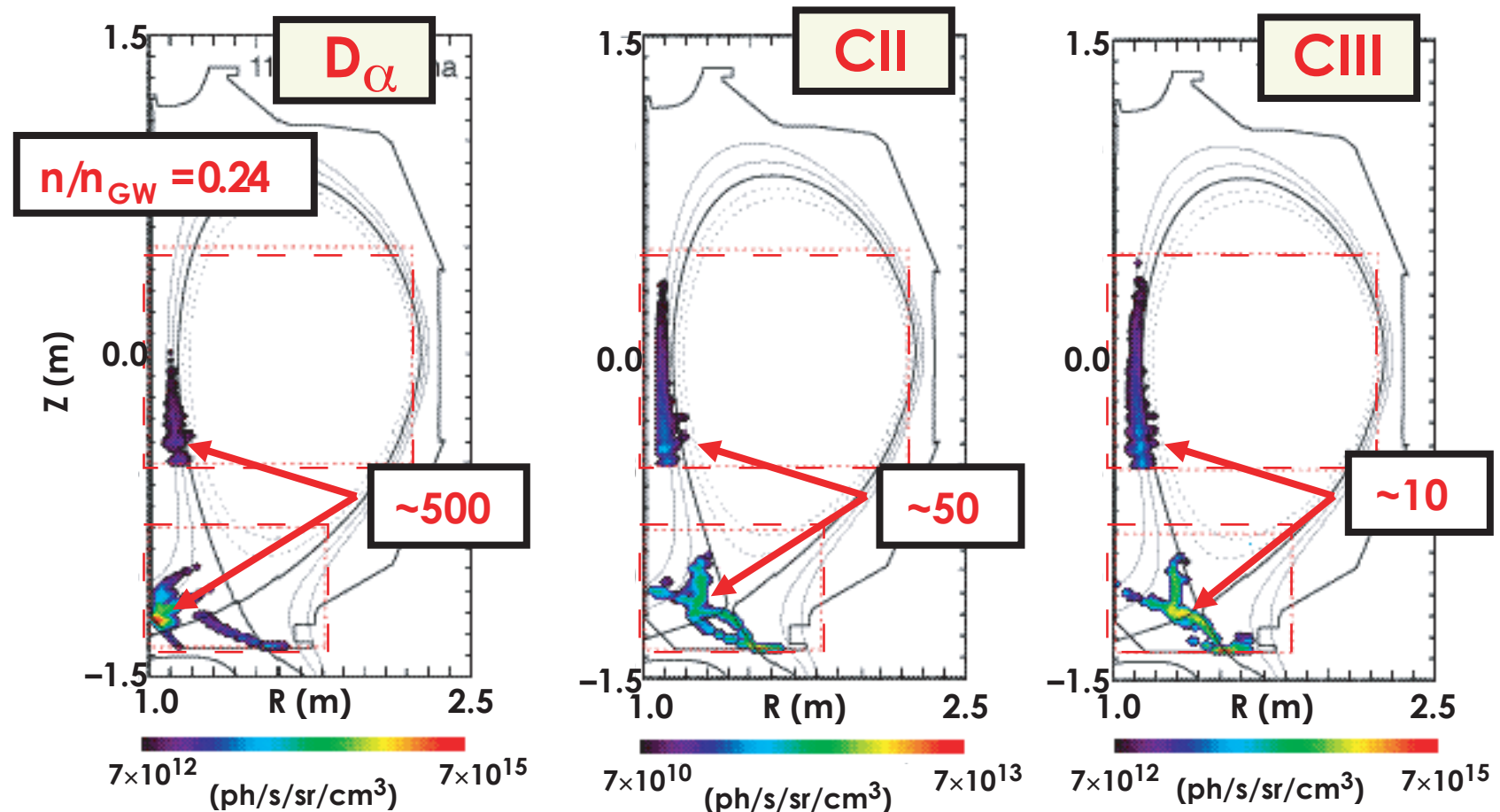
Enrichment was relatively insensitive to Γ_{AR} , with $\Gamma_{D2} \sim \text{constant}$

Direct Measurements of Recycling and Impurity Influx Compared With UEDGE Modeling are Important to Guide ITER Operation

- Deuterium neutral distribution can be explained by recycling at the divertor target plates and neutral transport into the main chamber
- Poloidal core plasma fueling profile is determined by fueling in the divertor X-point region and neutral leakage from divertor
- Carbon is produced mainly at the divertor plates and walls, due to chemical sputtering processes

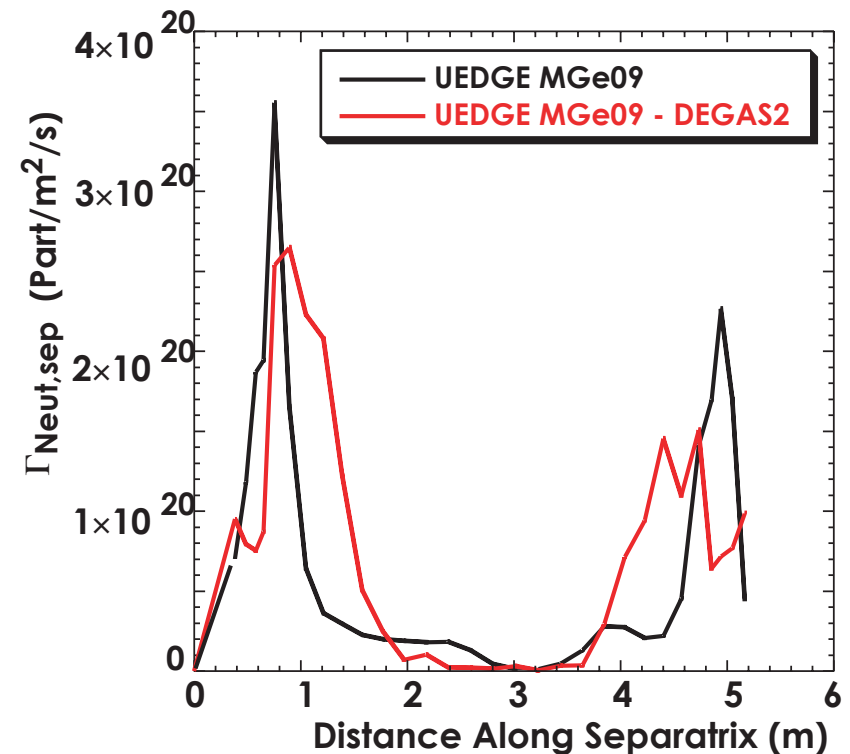
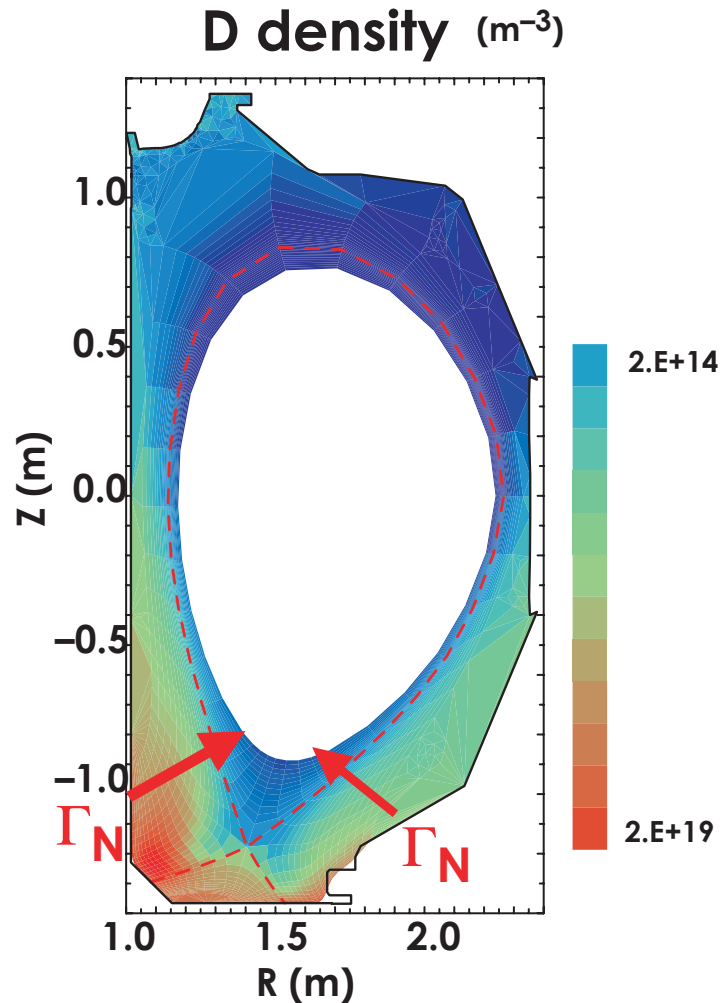


2-D DIII-D Data Shows Deuterium and Carbon Emission is Predominantly From The Divertor Region



- Plan: outer midplane views, high density operation, comparison with C-Mod picture frame data

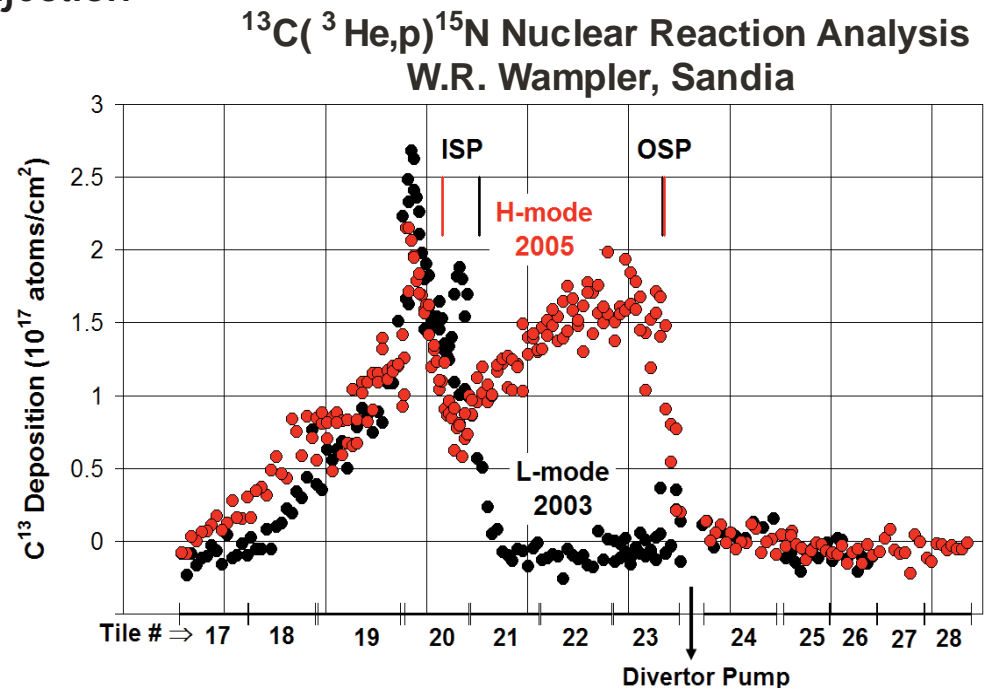
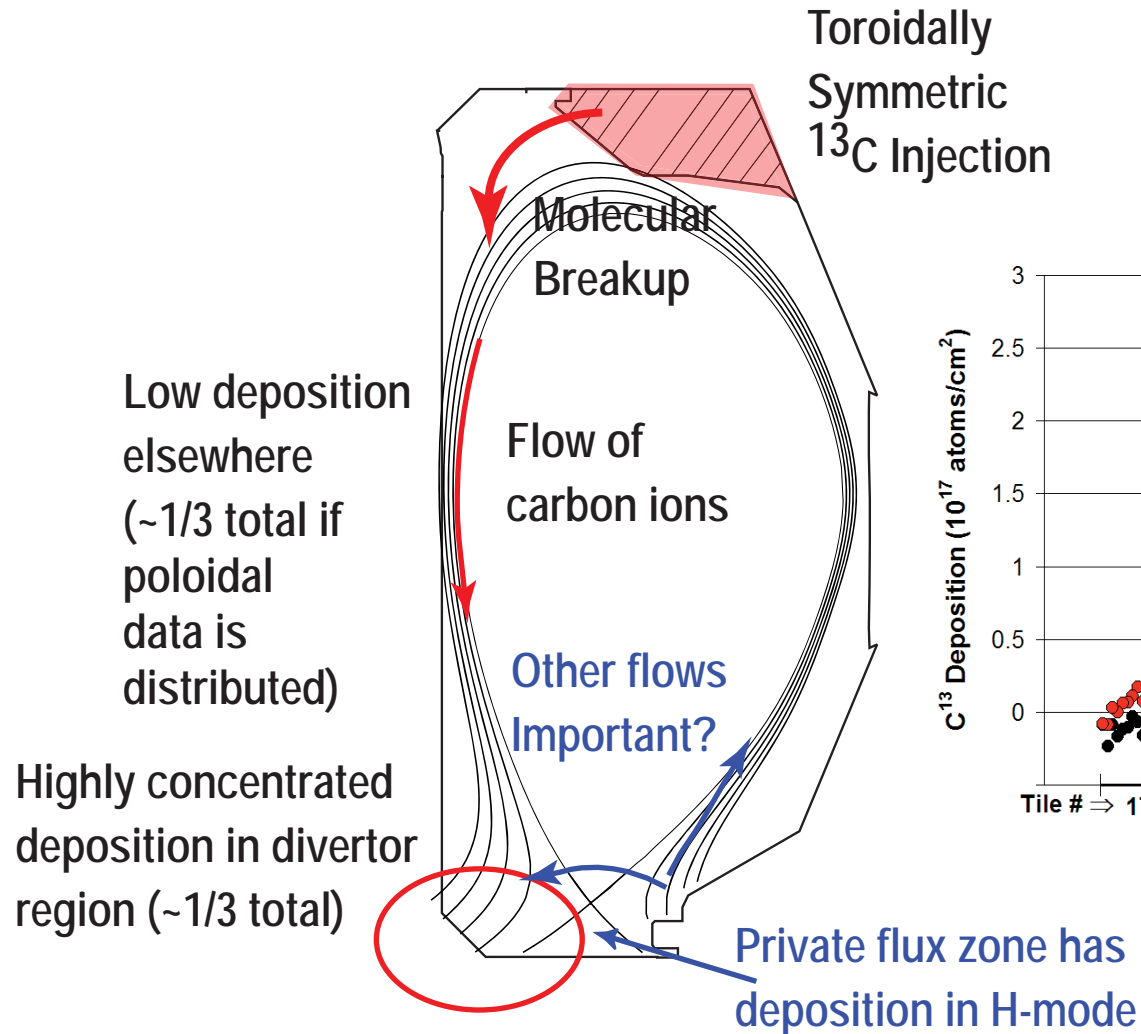
UEDGE/DEGAS2: Core Plasma is Fueled Through Divertor X-Point Region and by Divertor Neutral Leakage



Inboard X-point → Outboard X-point

*2006: New midplane views to measure
main chamber interaction, also
probes and MiMES*

^{13}C tracer injection in DIII-D has proven to be remarkably revealing (ITER tritium inventory)



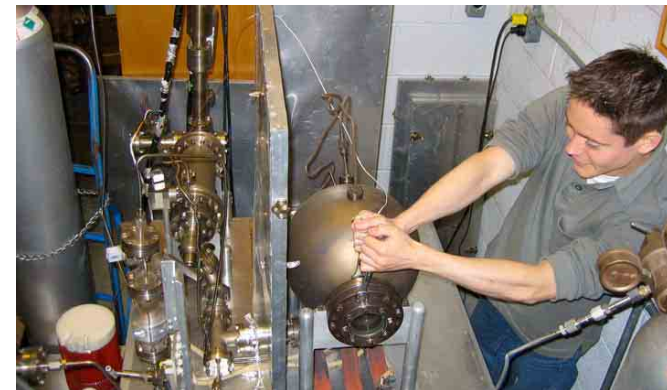
Low ^{13}C deposition found away from divertor

- Detecting main chamber ^{13}C deposition requires higher sensitivity
 - $^{13}\text{C}(p,\gamma)^{14}\text{N}$ nuclear reaction resonance at the U. Wis. (D.G. Whyte)
 - 10X lower detection limit
 - If small poloidal sample is representative, accounts for $\sim 1/3$ of total
- ^{13}C thermal oxidation facility (J.W. Davis) at U. Toronto (J.W. Davis)
 - 20 tiles planned to be tested

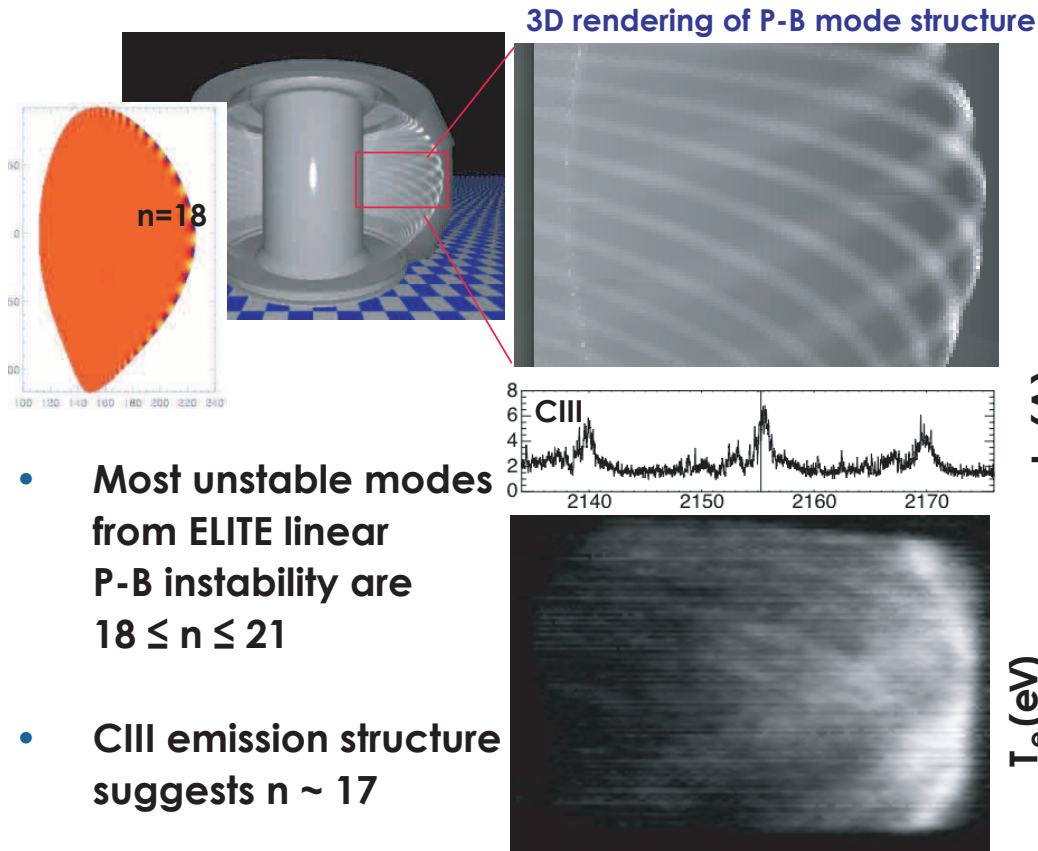
Ion beam analysis facility
University of Wisconsin



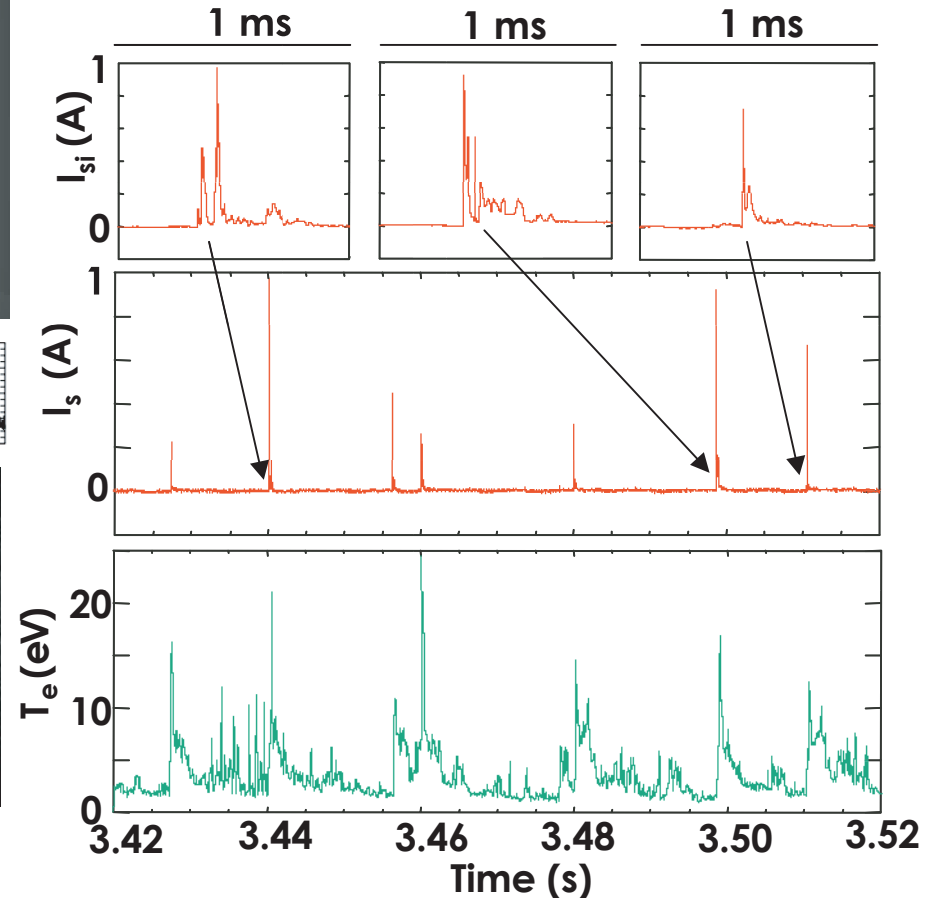
Oxidation facility
University of Toronto



ELMs show Peeling-Ballooning structure and expel bursts of density at main wall



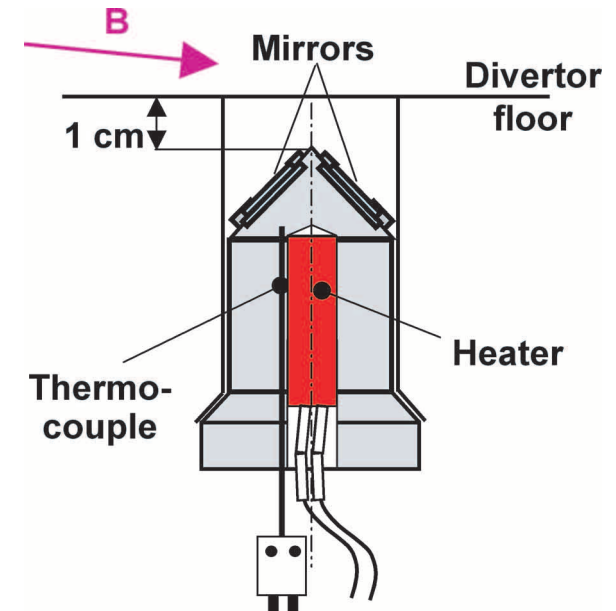
I_s and T_e midplane scanning probe



2006: New midplane MiMES with probe capabilities

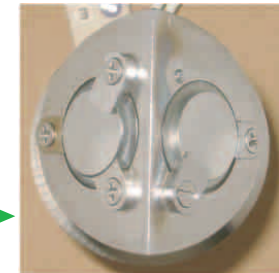
Divertor mirror deposition is temperature sensitive ($\sim 100^\circ$)

- **Diagnostic plasma facing mirrors are listed as high-priority ITPA topic**
 - ITER divertor mirrors will have deposition
- **No mirrors were exposed in the Private Flux zone of Detached ELMinG H-mode discharges**
 - Room temperature (6 shots, 25 s)
 - $\sim 100^\circ\text{C}$ (not constant) (17 shots, 70 s)



Visible deposits were observed on the mirrors exposed at room temperature

No deposits were observed on the mirrors exposed at elevated temperature !!

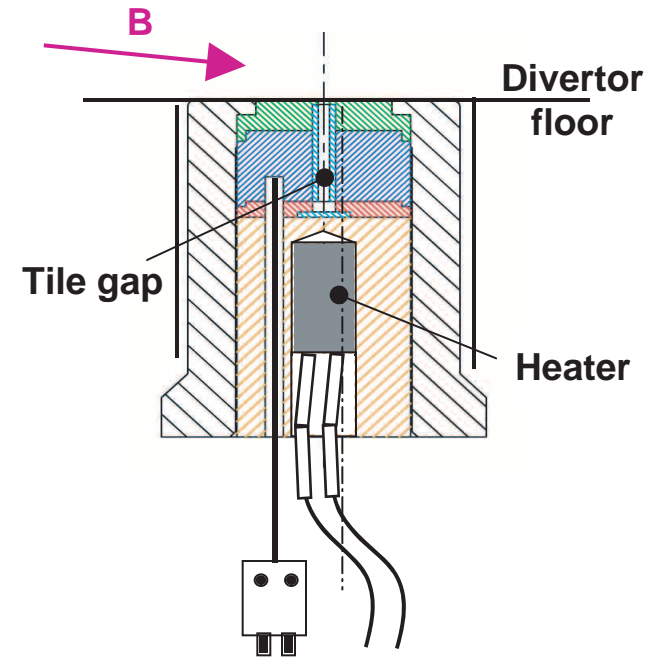


– Plan to repeat in 2006 with constant temperature

Deposition in tile gaps is reduced at higher temperature

- Tritium co-deposition with carbon in tile gaps is a serious potential problem for ITER
- DiMES sample with a simulated tile gap 2 mm wide and 15 mm near the detached OSP in two sets of identical L-mode discharges
- First exposure was performed at room temperature, second exposure was with sample heated to 200°C
- C:D films deposited in the gap at room temperature were of the “soft” amorphous type with D/C atomic ratio of 0.3–0.6
- Amount of co-deposited deuterium in the heated exposure was an order of magnitude lower than at room temperature
- A rather high net carbon erosion rate of 3 nm/s was measured at the sample surface in heated exposure

2006: Repeat with controlled temperature

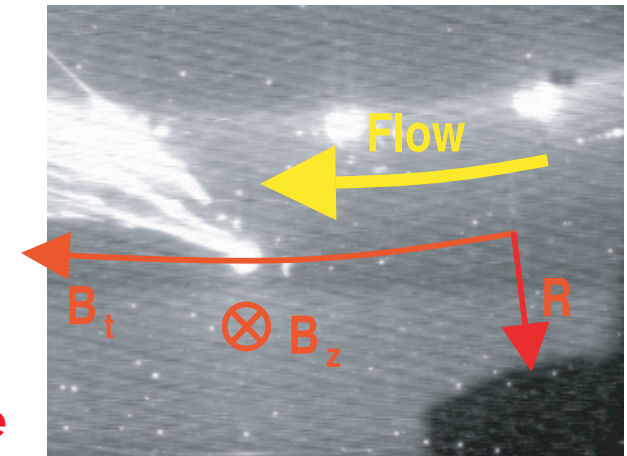


DUST is identified as an important ITPA topic

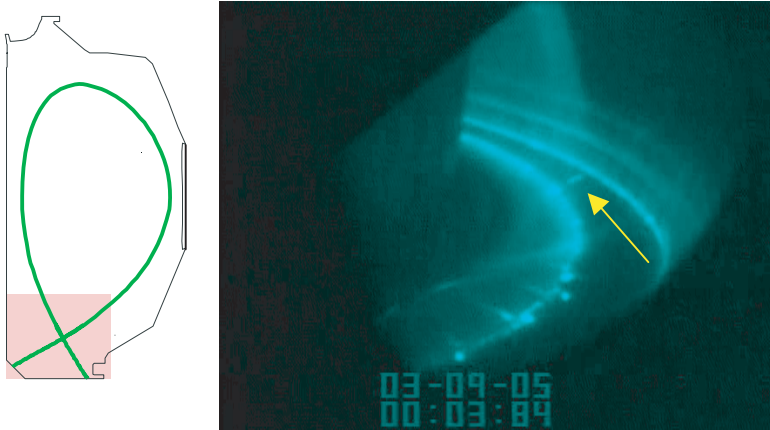
- During dust DiMES experiments cameras with near IR filters observed individual dust particles moving with velocities of 10–100 m/s
- Direction of the dust trajectories can be explained by a combination of the ion drag, Coulomb forces, and ion pre-sheath drifts

“Statistics” being developed
Thomson Scattering - 400/cubic meter, 80 nm average

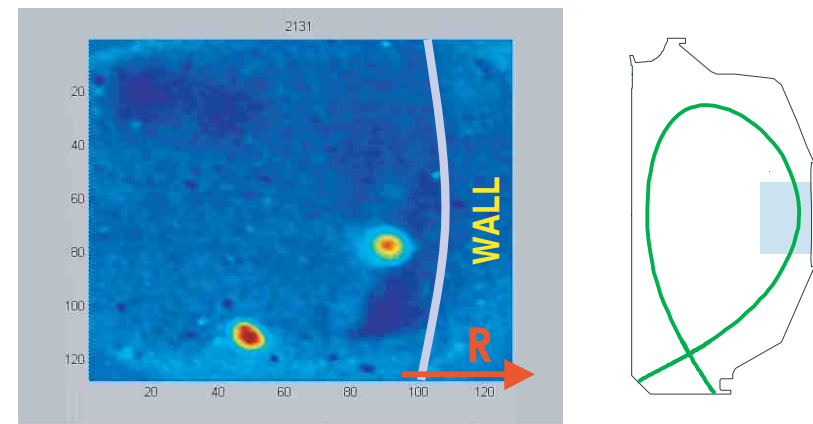
Top view (DiMES TV)



Tangential divertor camera (LLNL)

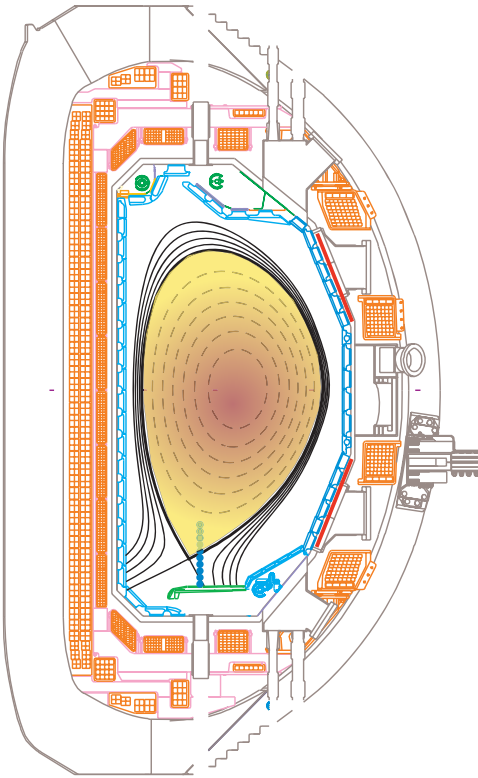


Fast-framing midplane camera (UCSD)



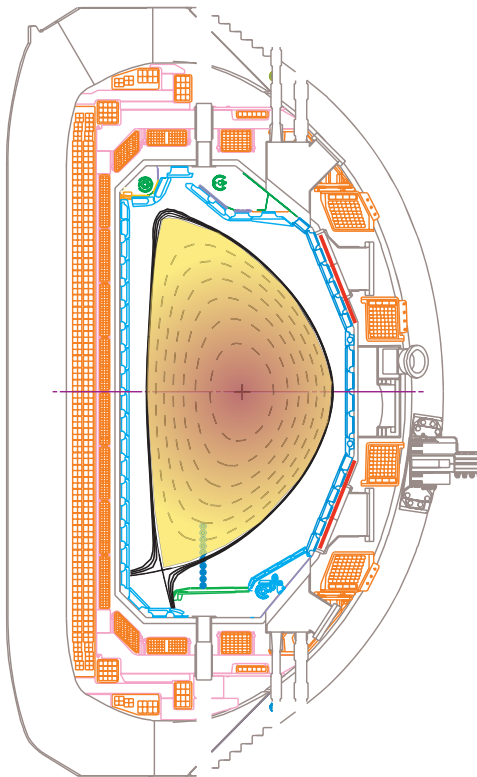
ITER-relevant boundary studies with the new AT divertor

Flexible Divertor Studies



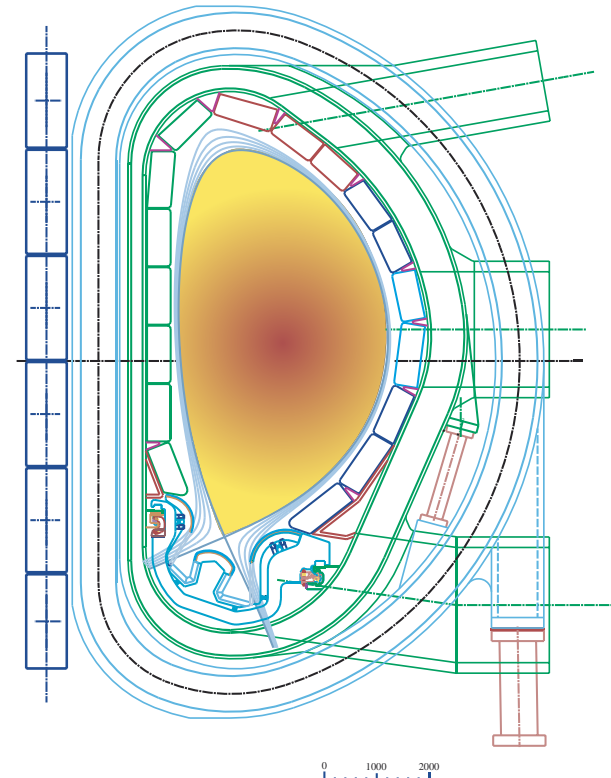
- Strike point on shelf
- Plasma sweeping for 2-D profile
- Baffle allows new views

SN ITER shape (also DN)

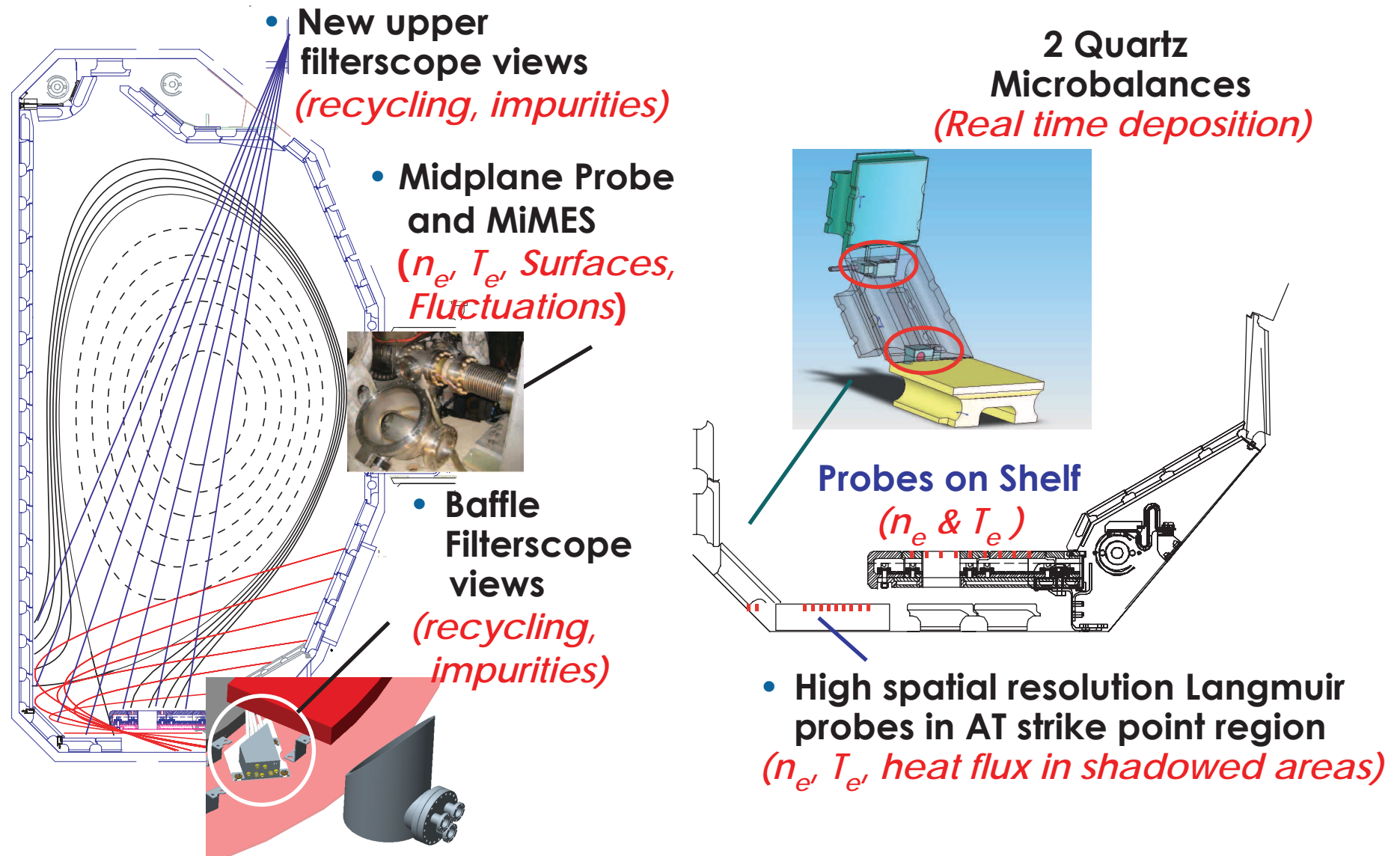


- Either SN (ITER) or DN (AT) shapes
- New probes and views for this shape

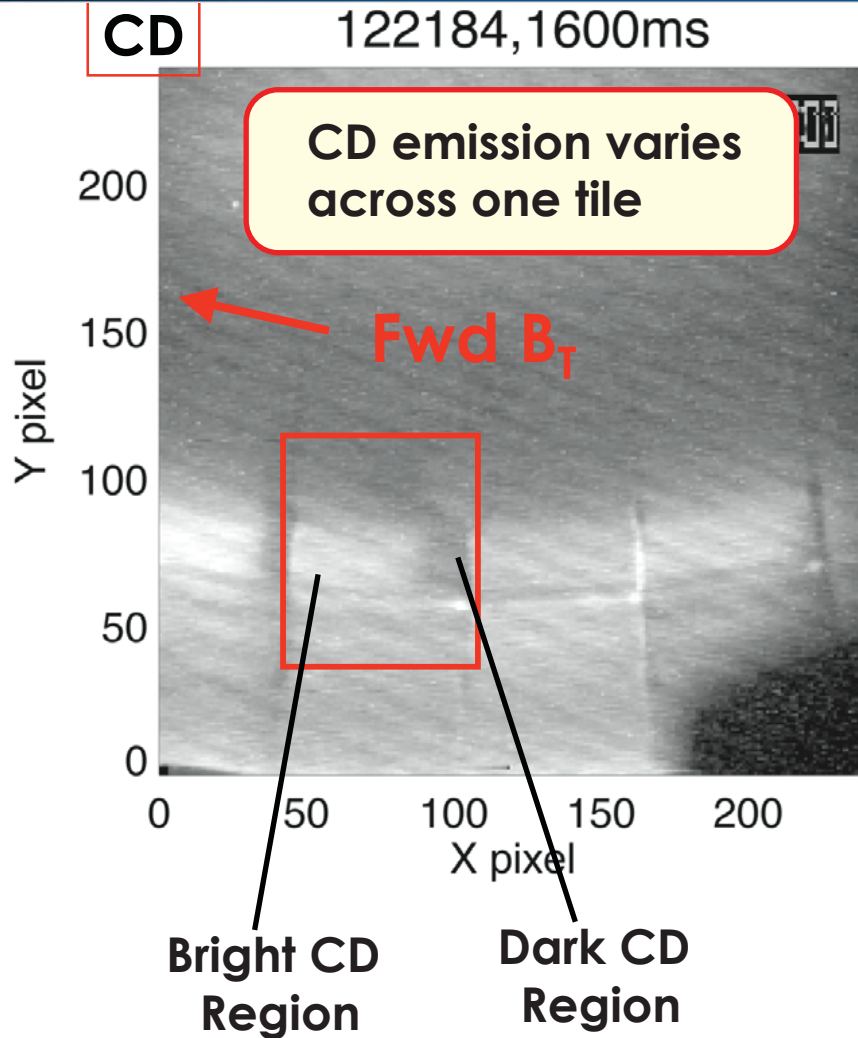
ITER (scaled)



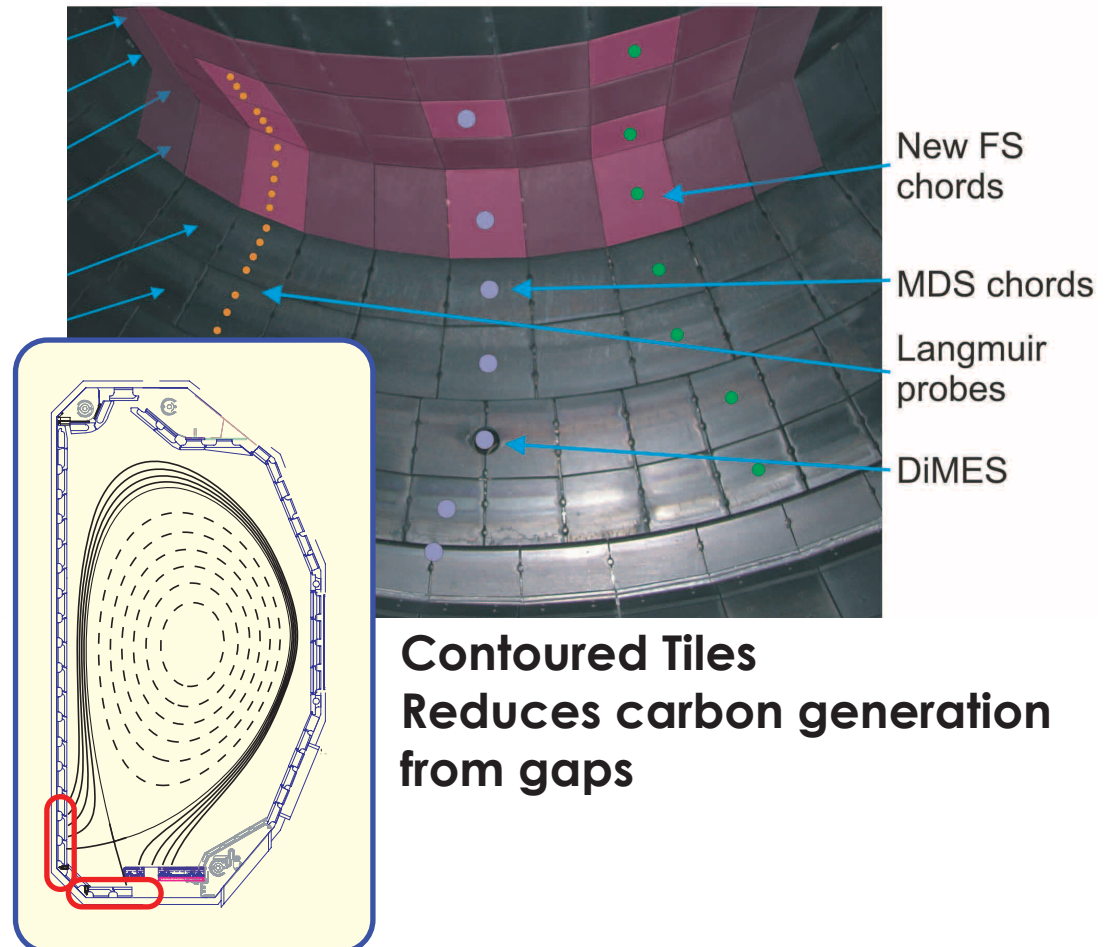
New divertor measurements in the DN AT divertor



Diagnostic divertor area will have contoured tiles



New Divertor will have contoured tiles in lower divertor and up the centerpost



ITER needs : Design Issues and ITPA tasks

- **Design issues that need ITPA input (Shimada, IT)**
 - a. Heat load on first wall, especially due to ELMs
 - b. Carbon erosion/deposition/control of tritium inventory and material choice
 - c. Private region PFC and necessity of Dome
- **ITPA High Priority Research Tasks and ITPA/IEA Experiments 2005-6**
 - d. Understand the effect of ELM/disruptions and first wall structures
 - e. Improve understanding of Tritium retention & the processes that determine it and development of efficient T removal methods
 - f. Develop improved prescription of SOL perpendicular coefficients and boundary conditions for input to BPX modeling
 - g. Determine life-time of plasma facing mirrors used in optical systems
 - h. Development of measurement requirements for dust

Boundary TSA working groups are organized around physics issues

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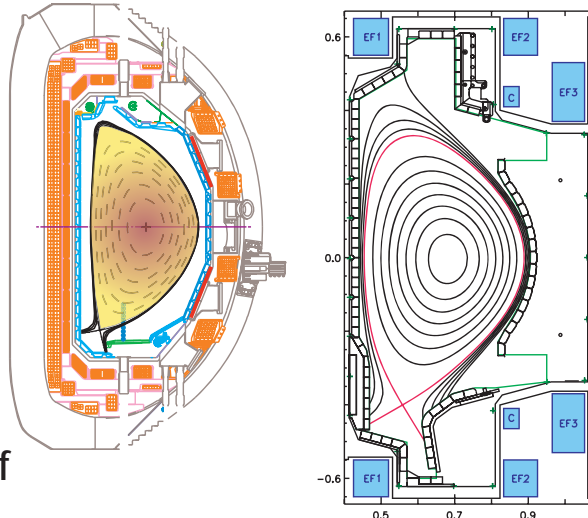
(Assumes no ^{13}C exposure in 2006)

DIII-D in the context of world tokamaks contributing to ITER

DIII-D

- Particle control in AT shape
- Carbon: erosion/redeposition
- ITER mirror and tile gap
- DN, divertor dome
- Simple flow diagnostics
- Modeling - Data comparison

NSTX and MAST - comparisons of divertor detachment & ELMs



C-MOD

- High n_e and power density
- Moly walls, wall coatings
- Main chamber vs. divertor particle sources
- SOL transport
- Mixed materials studies

JET

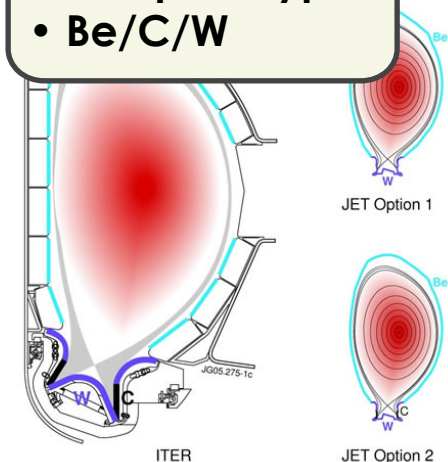
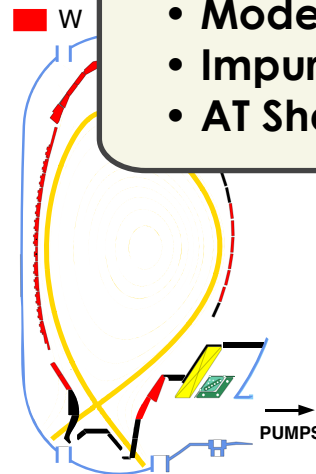
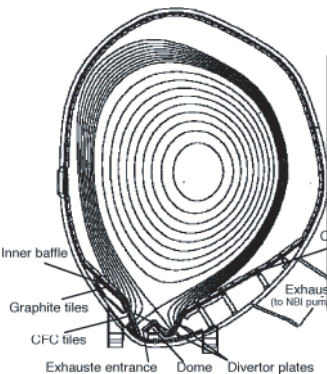
- Major Wall program
- ITER prototype
- Be/C/W

ASDEX -U

- Extensive W
- Modeling gaps
- Impurity transport
- AT Shapes

JT-60U

- Divertor Dome
- Carbon Walls
- Extensive flow probes
- AT Plasmas



These are “icons” - not to scale

ITER site decision provides focus for DIII-D Boundary Program

- a. Heat load on first wall, especially due to ELMs
- d. Understand the effect of ELM/disruptions and first wall structures

*Continued work with new diagnostics - probes, main chamber camera
Radiative divertor in Hybrid mode*

- b. Carbon erosion/deposition/control of tritium inventory and material choice
- e. Improve understanding of Tritium retention, processes, and T removal

^{13}C experiments, DiMES, and modeling (DIVIMP, UEDGE), side lab O_2 bake

- g. Determine life-time of plasma facing mirrors used in optical systems
- h. Development of measurement requirements for dust

TS for dust, dust during commissioning)

- c. Private region PFC and necessity of Dome

*New divertor geometry with and without dome, SN, DN - **effect of drifts***

- f. Develop SOL perpendicular coefficients and B.C. for input to BPX modeling

Comprehensive diagnostic set compared with computational models:

*UEDGE, BOUT, DIVIMP, DEGAS-2, BOUT-Kinetic -- **with particle drifts***